APPENDIX A

SAMPLE PROBLEMS

A-1. Sedimentation.

a. Design requirements and criteria. Design a sedimentation unit to provide settling for a sewage flow rate of 4 mgd with suspended solids concentration of 300 mg/l. The following conditions apply:

Surface loading rate = 600 gpd/square foot
Suspended solids removal = 60 percent
Sludge solids content = 4 percent
Sludge specific density = 1.02

b. Calculations and results.

(1) Calculate total tank surface area,

$$\text{Surface Area} = \frac{\text{Flow Rate}}{\text{Surface Loading Rate}} = \frac{4{,}000{,}000\ \text{gpd}}{600\ \text{gpd/square foot}} = 6{,}666.7\ \text{square feet}$$

use 6,670 square feet

(2) Using a depth of 8 feet, calculate total volume.

$$V = 8 \times 6{,}670 = 53{,}360\ \text{cubic feet}$$

(3) This volume can be divided among three rectangular tanks (in parallel) 20 feet wide and 120 feet long with a length-to-width ratio of 6 to 1. Two circular tanks (in parallel) 65 feet in diameter would also be suitable. This will provide flexibility of operation during routine or emergency maintenance and operations cleaning and repair of the units.

(4) Calculate weir length requirement assuming three rectangular tanks and allowable weir loading rate of 12,000 gpd/linear foot.

$$\text{Design Flow per Tank} = \frac{\text{Total Flow}}{3} = \frac{4{,}000{,}000\ \text{gpd}}{3} = 1{,}333{,}333\ \text{gpd}$$

$$\text{Weir Length/Tank} = \frac{1{,}333{,}333\ \text{gpd}}{12{,}000\ \text{gpd/linear foot}} = 111\ \text{linear feet}$$

(5) Compute weight of solids removed assuming 60 percent removal:

Weight Removed = 4 mgd x 300 mg/l x 8.34 pounds/gallon x 0.60

= 6,000 pounds/day

Therefore 1,500 pounds are removed per 1 mgd flow.

(6) Calculate sludge volume assuming a specific gravity of 1.02, and a moisture content of 96 percent (4 percent solids),

$$\text{Sludge Volume} = \frac{6{,}000 \text{ pounds/day}}{1.02(62.4 \text{ pounds/cubic foot})(0.04)}$$

= 2,360 cubic feet/day (at 4 mgd)

= 17,700 gpd

(7) Sludge handling in this example consists of removing sludge from the settling tank sludge hopper using a telescoping sludge valve which discharges the sludge into a sump from which it is removed by a sludge pump (or pumps). Assume that the sludge will be wasted every 8 hours and pumps for one-half hour to the digester.

$$\text{Sludge Sump Capacity} = \frac{\text{Daily Sludge Volume}}{\text{Number of Wasting Periods Per Day}}$$

$$= \frac{2{,}360 \text{ cubic feet}}{3}$$

= 787 cubic feet (= 5,900 gallons)

Increase capacity 10 percent to compensate for scum removal volumes:

$$\text{Sludge Pumping Capacity} = \frac{\text{Sludge and Scum Volume/Wasting Period}}{\text{30 minutes pumping/Wasting Period}}$$

$$= \frac{6{,}500 \text{ gallons}}{30 \text{ minutes}} = 217 \text{ gpm; use } 220 \text{ gpm}$$

c. Pumps. Pump types used to convey sludge include the plunger, progressing-cavity, centrifugal, and torque-flow. The pump information provided is for guidance only and does not represent design criteria. For more information, refer to Pump Application Engineering.

(1) Plunger. The advantages of plunger pumps may be listed as follows:

(a) Pulsating action tends to concentrate the sludge in the hoppers ahead of the pumps.

(b) They are suitable for suction lifts up to 10 feet, and are self-priming.

(c) Low pumping rates can be used with large port openings.

(d) Positive delivery is provided unless some object prevents the ball check valves from seating.

(e) They have constant but adjustable capacity, regardless of large variations in pumping head.

(f) Large discharge heads may be provided for.

(g) Heavy-solids concentrations may be pumped if the equipment is designed for the load conditions.

Plunger pumps come in simplex, duplex, and triplex models with capacities of 40 to 60 gpm per plunger, and larger models are available. Pump speeds will be between 40 and 50 rpm, and the pumps will be designed for a minimum head of 80 feet, since grease accumulations in sludge lines cause a progressive increase in head with use. Capacity is decreased by shortening the stroke of the plunger; however, the pumps seem to operate more satisfactorily at, or near, full stroke. For this reason, many pumps will be provided with variable-pitch V-belt drives for speed control of capacity.

(2) Progressing-cavity. The progressing-cavity pumps can be used successfully, particularly on concentrated sludge. The pump is composed of a single-threaded rotor that operates with a minimum of clearance in a double-threaded helix of rubber. It is self-priming at suction lifts up to 28 feet, is available in capacities up to 350 gpm, and will pass solids up to 1.125 inches in diameter.

(3) Centrifugal. With centrifugal pumps, the objective is to obtain a large enough pump to pass the solids without clogging and a small enough capacity to avoid pumping a sludge diluted by large quantities of the overlying sewage. Centrifugal pumps of special design can be used for pumping primary sludge in large plants (greater than 2 mgd). Since the capacity of a centrifugal pump varies with the head, which is usually specified great enough so that the pumps may assist in dewatering the tanks, the pumps have considerable excess capacity under normal conditions. Throttling the discharge to reduce the capacity is impractical because of frequent stoppages; hence it is essential that these pumps be equipped with variable-speed drives. Centrifugal pumps of the bladeless impeller type have been used to some extent and in some cases have been deemed preferable to either the plunger or screw-feed types of pumps. Bladeless pumps have approximately one-half the capacity of conventional nonclog pumps of the same nominal size and consequently approach the hydraulic

requirements more closely. The design of the pump makes clogging at the suction of the impeller almost impossible.

(4) Torque-flow. This type of pump, which uses a fully recessed impeller, is very effective in conveying sludge. The size of particles that can be handled is limited only by the diameter of the suction or discharge valves. The rotating impeller develops a vortex in the sludge so that the main propulsive force is the liquid itself.

(5) Pump application. Types of sludge that will be pumped include primary, trickling-filter and activated, thickened, and concentrated. Scum that accumulates at various points in a treatment plant must also be pumped.

(6) Primary sludge. Ordinarily, it is desirable to obtain as concentrated a sludge as practicable from primary tanks. The character of primary sludge will vary considerably, depending on the characteristics of the solids in the wastewater, the types of units and their efficiency, and where biological treatment follows, the quantity of solids added from:

- Overflow liquors from digestion tanks,

- Waste activated sludge,

- Humus sludge from settling tanks following trickling filters.

Primary sludge should be given special consideration since it is denser, and contains more grit and trash than secondary sludge. Pumps having any chance of clogging will not be used. Plunger pumps may be used on primary sludge. Centrifugal pumps of the screw-feed and bladeless type, and torque-flow pumps may also be used.

(7) Trickling-filter and activated sludge. Sludge from trickling filters is usually of such homogeneous character that it can be easily pumped with either plunger or nonclog centrifugal pumps. Return activated sludge is dilute and contains only fine solids, so that it may be pumped readily with nonclog centrifugal pumps, which must operate at slow speed to help prevent the flocculent character of the sludge from being broken up.

(8) Scum pumping. Screw-feed pumps, plunger pumps, and pneumatic ejectors may be used for pumping scum. Bladeless or torque-flow centrifugal pumps may also be used for this service.

A-2. Single stage stone-media trickling filters.

a. Design requirements and criteria. Design a trickling filter to treat 2 mgd of primary settled effluent, under the following conditions:

Raw wastewater BOD = 250 mg/l

Primary clarifier BOD removal efficiency = 30 percent

Required effluent BOD = 30 mg/l

Design temperature 20 degrees C.

Design without and with recirculation

b. Calculations and results.

(1) Design without recirculation. Therefore, R = 0, F = 1

Primary treated effluent BOD = 250(1-0.3) = 175 mg/l

$$\text{Required Trickling Filter Efficiency} = \frac{175-30}{175}$$

$$= 0.83$$

Since the design temperature is 20 degrees C. no temperature correction is required.

BOD loading to the filter =

$$(2.0 \text{ mgd}) \times (175 \text{ mg/l}) \times \frac{8.34 \text{ pounds/mil gallon}}{\text{mg/l}}$$

$$= 2{,}920 \text{ pounds/day}$$

Assume a practical filter depth of 6 feet for stone-media filters. Apply NRC formula

$$E = \frac{100}{1 + 0.0085\sqrt{W/VF}}$$

Resulting in

$$83 = \frac{100}{1 + 0.0085\sqrt{2{,}920/V}}$$

Solving for the volume

$$V = 5.03 \text{ acre feet}$$

$$= 219{,}000 \text{ cubic feet}$$

With a filter depth of 6 feet, filter area, A = 219,000/6 = 36,500 square feet; therefore, to allow for plant flexibility and partial treatment should a filter require maintenance, a minimum of two filters should be provided.

$$\text{Filter area (each)} = \frac{36{,}500}{2} = 18{,}250 \text{ square feet}$$

$$A = \frac{\pi D^2}{4}$$

$$\text{or } D = \sqrt{\frac{A \times 4}{\pi}}$$

$$\text{Therefore } D = \sqrt{\frac{18{,}250 \times 4}{\pi}} = 152 \text{ feet (each filter)}$$

use 155 feet

(2) Design with 1:1 recirculation

$$\text{Recirculation factor } F = \frac{1 + R}{(1 + 0.1R)^2} = 1.65$$

$$E = \frac{100}{1 + 0.0085\sqrt{W/VF}}$$

$$83 = \frac{100}{1 + 0.0085\sqrt{\frac{2{,}920}{1.65V}}}$$

or, V = 3.05 acre feet

$$A = \frac{132{,}760}{6}$$

= 22,100 square feet; again use two filters.

Filter diameter D = 119 feet; use 120 feet (each filter).

(3) Design with 2:1 recirculation

$$\text{Recirculation factor } F = \frac{1 + 2}{(1 + 0.1 \times 2)^2}$$

$$0.83 = \frac{1}{1 + 0.0085\sqrt{\frac{2{,}920}{2.08V}}}$$

V = 2.4 acre feet

Filter area = $\frac{2.4 \times 43,560}{6}$ = 17,500 square feet; again use two filters

Filter diameter = 105 feet (each filter)

c. Pumps. Recirculation pumps will be sized to provide constant rate recirculation. Vertical-shaft, single suction units, installed in a dry well, with motors mounted on top of the pumps, or on an upper floor will be used. Each pump will be provided with its individual pipe connection to the wet well.

A-3. Two stage stone-media trickling filters.

a. Design requirements and criteria. Design a two-staged trickling filter to treat 3.0 mgd of primary settled effluent, assuming the following conditions.

Raw wastewater BOD = 250 mg/l

Primary clarified BOD removal efficiency = 30 percent

Required effluent BOD = 30 mg/l

Design temperature = 20 degrees C.

b. Calculations and results.

Primary clarifier effluent BOD

= 250 (1 - 0.3)

= 175 mg/l

Overall trickling filter efficiency

$= \frac{175-30}{175}$

= 0.828

Filter Depth = 6 feet

Recirculation = 2:1

Assuming that the first stage filter efficiency = 75 percent

Overall efficiency = 0.828

$$= E_1 + E_2 (1 - E_1)$$

$$= 0.75 + E_2 (1 - 0.75)$$

$$E_2 = 0.31$$

Recirculation factor $F = \dfrac{1 + R}{(1 + 0.1R)^2}$

$$= \frac{1 + 2}{(1 + 0.1 \times 2)^2} = 2.08$$

Organic loading to first stage filter,

W = 3.0 mgd x 8.34 x 250(1-0.30) = 4,379 pounds/day;
use 4,380 pounds/day

Now using the NRC formula

$$E_1 = \frac{1}{1 + 0.0085\sqrt{\frac{W}{VF}}}$$

$$0.75 = \frac{1}{1 + 0.0085\sqrt{\frac{4,380}{2.08V}}}$$

V = 1.37 acre feet

Filter area= $\dfrac{1.37 \times 43,560}{6}$ = 9,946 square feet;

Use two filters, 5,000 square feet each

Filter diameter = 79.8 feet, use 80 feet (each filter)

Design second stage filter:

Organic loading, W' = W (1 - 0.75)

= 4,380 (1 - 0.75)

= 1,095 pounds/day

$$E_2 = \frac{1}{1 + \frac{0.0085}{1-E_1}\sqrt{\frac{W'}{V'F}}}$$

$$0.31 = \frac{1}{1 + \frac{0.0085}{1 - 0.75}\sqrt{\frac{1,095}{2.08V'}}}$$

V' = 0.122 acre feet

Filter area $A = \frac{0.122 \times 43,560}{6}$ = 892 square feet; use one filter

Filter diameter D = 33.7 feet; use 35-foot filter

A-4. Plastic-media trickling filters.

a. Design requirements and criteria. Design a plastic media trickling filter to treat 2 mgd of primary settled effluent, assuming the following conditions:

Raw wastewater BOD = 250 mg/l

Primary clarifier BOD removal efficiency = 30 percent

Required final effluent BOD = 25 mg/l

Winter design temperature = 10 degrees C.

b. Calculations and results. The formula presented in paragraph 10-2.f.(2) states the following with L_e and L_o in units of mg/l, K_{20} as day^{-1}, D as feet, and Q as gpm/square foot.

$$\frac{L_e}{L_o} = \exp\left[\frac{-\theta^{T-20} K_{20} D}{Q^n}\right]$$

The raw waste BOD = 250 mg/l; 30 percent removal is obtained in the primary clarifiers; therefore:

L_o = 250 x (1-0.3) = 175 mg/l

L_e = 25 mg/l based on local, state, and Federal requirements

Assume a filter depth of 12 feet:

$$\frac{25}{175} = \exp\left[\frac{-[1.035^{(10-20)}](0.088)(12)}{Q^{0.67}}\right]$$

therefore,

$$0.143 = \exp\left[\frac{-0.75}{Q^{0.67}}\right]$$

Taking the natural logarithm of both sides of the equation results as follows:

$$\ln 0.143 = -\left[\frac{0.75}{Q^{0.67}}\right] \ln e$$

$$-1.94 = -\left[\frac{0.75}{Q^{0.67}}\right] \times 1.0$$

$$Q^{0.67} = 0.75/1.94$$

$$Q^{0.67} = 0.387$$

$$Q = (0.387)^{1.49}$$

$$= 0.243 \text{ gpm/square foot}$$

Required surface area can be computed by:

$$\text{Surface area} = \frac{\text{Flow}}{Q}$$

$$\text{Surface Area} = \frac{\dfrac{2 \times 10^6 \text{ gpd}}{1{,}440 \text{ minutes/day}}}{0.243 \text{ gpm/square foot}} = 5{,}716 \text{ square feet}$$

use 5,720 square feet

$$\text{Since } A = \frac{\pi D^2}{4}$$

$$\frac{\pi D^2}{4} = 5{,}720$$

$$D = \sqrt{\frac{5{,}720 \times 4}{\pi}} = 85.4, \text{ use 86 feet}$$

Therefore, the filter dimensions should be:

86 feet diameter by 12 feet deep

Plastic media manufacturers will be consulted to determine the exact proportions of filter media that provides for a minimum of 5,720 square feet area and 12-foot depth.

A-5. Activated sludge, plug flow aeration.

a. Design requirements and criteria. Design an activated sludge plant to treat 2 mgd of settled domestic wastewater, assuming the following conditions:

Raw wastewater BOD = 250 mg/l

BOD removal in primary clarifier = 20 percent

Final effluent BOD = 20 mg/l

b. Calculations and results. Design for 50 percent recycle. The required activated sludge removal efficiency is calculated as follows:

$$E = \frac{\text{Raw BOD x (1 - BOD removed in primary) - effluent BOD}}{\text{Raw BOD x (1 - BOD removed in primary)}}$$

$$= \frac{250(1 - 0.2) - 20}{250(1 - 0.2)} = 0.90$$

BOD applied = (0.8) (250) = 200 mg/l

Converting to pounds/day:

2 x 200 x 8.34 = 3,340 pounds/day applied

Check detention time:
From table 11-2:

BOD loading = 40 pounds/1,000 cubic feet tank/day, therefore,

$$\text{Tank Vol} = \frac{\text{3,340 pounds/day}}{\text{40 pounds/day/1,000 cubic feet}} = \text{83,500 cubic feet}$$

(will provide 7 hour 30 minute aeration at average flow)

$$\frac{\text{624,580 gallons}}{2 \times 10^6 \text{ gallons/day}} \times \text{24 hours/day} = \text{7.4 hours - O.K.}$$

Required depth = 12 feet SWD + 2 feet freeboard

Required width = 2 x SWD = 2 x 12 = 24 feet

therefore, $\text{Length} = \frac{\text{Vol}}{\text{W x D}} = \frac{83,500}{12 \times 24} = 290 \text{ feet}$

Total tank dimensions 290 feet by 24 feet by 14 feet

From table 11-3:

Aeration requirements
applied = 1,000 cubic feet/pound BOD
= 1,000 x 3,340 = 3,340,000 cubic feet/day
= 2,319 cfm required

The final clarifier is designed on the basis of surface loading equal to 600 gpd/square foot. Assume a depth of 8 feet.

Final clarifier area =

$$\frac{2 \times 10^6 \text{gpd}}{600 \text{ gpd/square foot}} = 3{,}333 \text{ square feet; use } 3{,}400 \text{ square feet}$$

Clarifier diameter = 65 feet

Compute clarifier detention time as a check:

$$t = \frac{3{,}400 \times 8 \times 7.48}{2 \times 10^6/24} = 2.4 \text{ hours}$$

A-6. Activated sludge, completely mixed aeration.

a. Design requirements and criteria. Design a completely mixed aeration tank to treat the same effluent described in example A-5.

b. Calculations and results. From table 11-2, BOD loading = 50 pounds BOD/1,000 cubic feet/day.

Therefore,

$$\text{Tank Volume} = \frac{3{,}340}{50/1{,}000} = 66{,}800 \text{ cubic feet}$$

or, converting to gallons:

66,800 cubic feet x 7.48 gallons/cubic feet = 500,000 gallons

Check detention time (table 11-2):

$$\frac{500{,}000 \text{ gallons}}{2 \times 10^6 \text{ gallons/day}} \times 24 \text{ hours/day} = 6 \text{ hours - O.K.}$$

Select SWD = 12 feet + 2 foot freeboard

Assume $\frac{L}{W} = 2$. Therefore: L x W x D = Volume

Since L = 2W

$2W^2 \times D = \text{Volume}$

$$W = \sqrt{\frac{\text{Volume}}{2D}} = \sqrt{\frac{66{,}800 \text{ cubic feet}}{2 \times 12 \text{ feet}}}$$

$$= 53 \text{ feet}$$

$L = 2W = 2 \times 53 = 106$ feet

Therefore use as basis -

110 feet by 55 feet by 14 feet

A-7. Anaerobic sludge digestion.

a. Design requirements and criteria. Determine the digester volume and gas yield and heat requirement for the anaerobic digestion of combined activated sludge and primary sludge. Assuming the following conditions apply:

Sludge amount = 1,200 pounds/day

Sludge solids after thickening = 3 percent

Detention time = 15 days

Volatile matter reduction = 60 percent

Temperature = 80 degrees F. (in digester)

Gas yield rate = 15 cubic feet/pounds VSS destroyed

Volatile sludge content = 75 percent

b. Calculations and results.

(1) Determine digester volume,

$$\text{sludge volume} = \frac{1{,}200 \text{ pounds/day}}{8.34 \times 0.03} = 4{,}796 \text{ gpd;}$$

use 4,800 gpd

$$= 4{,}800 \times \frac{1}{7.48} = 642 \text{ cubic feet/day}$$

digester volume = 642 cubic feet/day x 15 days = 9,630 cubic feet

(2) Determine gas yield

$$\text{Gas yield} = 15 \frac{\text{cubic feet}}{\text{pound VSS destroyed}}\ 1{,}200 \text{ pounds/day} \times 0.75 \times 0.60$$

$$= 8{,}100 \text{ cubic feet/day} = 5.6 \text{ cfm}$$

(3) Using a circular tank 20 feet deep and 26 feet in diameter, determine the heat requirement. Given:

Heat Transfer Coefficient Btu/hour/square foot/degrees F.	Temperature degrees F.	
Walls = 0.14	(air)	40
Floor = 0.12	(ground)	50
Roof = 0.16	(air)	40

Area

Walls = π (26)(20) = 1,634 square feet

Floor = π $(13)^2$ = 531 square feet

Roof = π $(13)^2$ = 531 square feet

Heat Loss

Walls = (0.14)(1,634)(80-40) = 9,150 Btu/hour

Floor = (0.12)(531)(80-50) = 1,908 Btu/hour

Roof = (0.16)(531)(80-40) = 3,392 Btu/hour

Total Heat Loss = 14,450 Btu/hour = 346,800 Btu/day

Sludge Heat Requirement = $\frac{\text{(1,200 pounds/day)}}{.03}$ (80-45) degrees F.

x 1.0 Btu/pound/degree F. = 1,400,000 Btu/day

Total Heat Requirement = 346,800 + 1,400,000

= 1,746,800 Btu/day

(4) Determine heat supplied by utilizing sludge gas, assuming a heat value of 600 Btu/cubic foot:

Heat from sludge gas = (8,100 cubic feet/day)(600 Btu/cubic foot)

= 4,860,000 Btu/day

A-8. Aerobic sludge digestion.

a. Design requirements and criteria. Determine digester volume and air requirements for the aerobic digestion of activated sludge after thickening. Assume the following conditions apply:

Sludge quantity = 1,200 pounds/day

Sludge concentration = 3 percent

Detention time = 20 days

Air supply requirement = 30 cfm/1,000 cubic feet digester volume

b. Calculations and results.

(1) Determine digester volume,

$$\text{Sludge volume} = \frac{1{,}200 \text{ pounds/day}}{8.34 \quad (0.03)} = 4{,}796 \text{ gallons/day}$$

$$= 4{,}796 \times \frac{1 \text{ cubic foot}}{7.48 \text{ gallons}} = 641 \text{ cubic feet/day}$$

Digester volume = 641 cubic feet/day x 20 days = 12,820 cubic feet

(2) Determine air requirement:

Air required = (12,820 cubic feet)(30 cfm/1,000 cubic feet)

= 384.6 cfm; use 385 cfm

(this also satisfies mixing requirements).

A-9. Sludge pumping.

a. Design requirements and criteria. Determine the horsepower and pressure requirements for pumping sludge from a settling tank to a thickener. Assume the following conditions apply:

Sludge is pumped at 6 fps

150 feet of 8 inches pipe is used

Thickener is 10 feet above settling tank (elevation difference = 10 feet)

Sludge specific gravity = 1.02

Sludge moisture content = 95 percent

Pressure at inlet side of pump = 3 psi

Coefficient of friction = 0.01

b. Calculations and results.

(1) Calculate head loss using the Darcy-Weisbach equation to give friction loss, F (for water):

$$F = \left(\frac{fL}{D}\right)\frac{V^2}{2g}$$

where:

f = coefficient of friction
L = length of pipe, feet
D = diameter of pipe, feet
V = mean velocity, fps
g = gravity constant, feet/second^2

$$F = \frac{(0.01)(150\text{ feet})}{(8\text{ inches} \times 1/12\text{ foot/inch})} \times \frac{(6\text{ fps})^2}{2(32.17\text{ feet/second}^2)}$$
$$= 1.3\text{ feet of fluid}$$

Assuming friction losses for sludge three times that for water, the head loss from friction is:

h_r = (1.3 feet)(3) = 3.9 feet; use 10 feet

(2) Calculate total pumping head

H = 10 feet + 10 feet = 20 feet of sludge

add 3 feet to this to account for losses due to valves, elbows, etc.

Total H = 23 feet of sludge

(3) Assuming a pump efficiency of 60 percent, calculate horsepower requirement

$$hp = \frac{QP_w(sp\ gr)H}{550\ e}$$

where:

hp = horsepower requirement
Q = fluid flow
P_w = density of water
sp gr = specific gravity of pumped fluid
H = total head
e = efficiency

$$Q = (6\ \text{fps}) \quad (0.333)^2 = 2.1\ \text{cfs}$$

hp =

$$\frac{(2.1\ \text{cfs})(62.4\ \text{pcf})(1.02)(23\ \text{feet})}{550(0.60)}$$

$$= 9.3\ \text{hp; use } 10\ \text{hp}$$

(4) Determine discharge pump pressure

$$P = \frac{(\text{Total head})(\text{sp gr})(w)}{144\ \text{square inches/square foot}}$$

$$= \frac{(23\ \text{feet})(1.02)(62.4\ \text{pcf})}{144\ \text{square inches/square foot}}$$

$$= 10.2\ \text{psi}$$

A-10. Chlorinator.

a. Design requirements and criteria. Determine the capacity of a chlorinator for an activated sludge wastewater treatment plant with an average flow of 2 mgd. The peaking factor for the treatment plant is 2.5. The average required chlorine dosage is 8 mg/l and the maximum required chlorine dosage is 20 mg/l. EPA regulations require 30-minute contact time at peak hour conditions.

b. Calculations and results.

(1) Determine capacity of the chlorinator at peak flow

pounds Cl_2/day = 20 mg/l x 8.34 pounds/gallon x 2 mgd x 2.5 = 834

Use four 250-pound/day units

(2) Estimate the daily consumption of chlorine.

Average dose = 8 mg/l

(see table 13-1)

pound Cl_2/day = 8 X 8.34 X 2.0

= 133.4; use 140

It should be noted that the total unit capacity is about six times the average needed chlorine. This is to cover the peak hydraulic flow of wastewater and to cover a wider range of dosage of chlorine that might be needed under unfavorable conditions. Space requirements for the four units and for storage of chlorine tanks is estimated to be about 400 square feet.

(3) Chlorine contact tank. Required volume for 30-minute contact time.

$$\text{Volume} = Q \times T$$

where:

Q = peak flow rate, gpm
T = detention time, minutes

$$\text{Vol} = \frac{2.0 \times 10^6 \text{ gallons/day}}{1,440 \text{ minutes/day}} (2.5)(30 \text{ minutes}) = 104,170 \text{ gallons}$$

$$= 13,930 \text{ cubic feet; use } 14,000 \text{ cubic feet}$$

Assume 6 feet SWD + 2 feet freeboard

Let $\frac{L}{W} = 10$ for plug flow tank; therefore,

$$L \times W \times D = \text{Volume}$$

Since L = 10W, therefore:

$$10\ W^2 = \frac{\text{Volume}}{D}$$

$$W = \sqrt{\frac{\text{Volume}}{10 \times D}} = \sqrt{\frac{14,000}{10 \times 6}}$$

$$= 15.3 \text{ feet}$$

$$L = 10W = 153 \text{ feet in length}$$

Therefore, the basic chlorine contact tank dimensions are:

153 feet by 15.3 feet by 8 feet (6 feet SWD)

Baffling is used to construct a more regular tank shape and to prevent flow short-circuiting. (Refer to EPA Process Design Manual for Upgrading Existing Wastewater Treatment Plants for layout of tank baffles). Using a flow channel width of 15.3 feet and 4 side-by-side plug flow compartments, the overall tank width is:

$$\frac{153 \text{ feet}}{4} = 38.3 \text{ feet}$$

The length is:

4 x 15.3 feet = 61.2 feet

The tank dimensions are therefore:

61.2 feet by 38.3 feet by 8 feet (6 feet SWD)